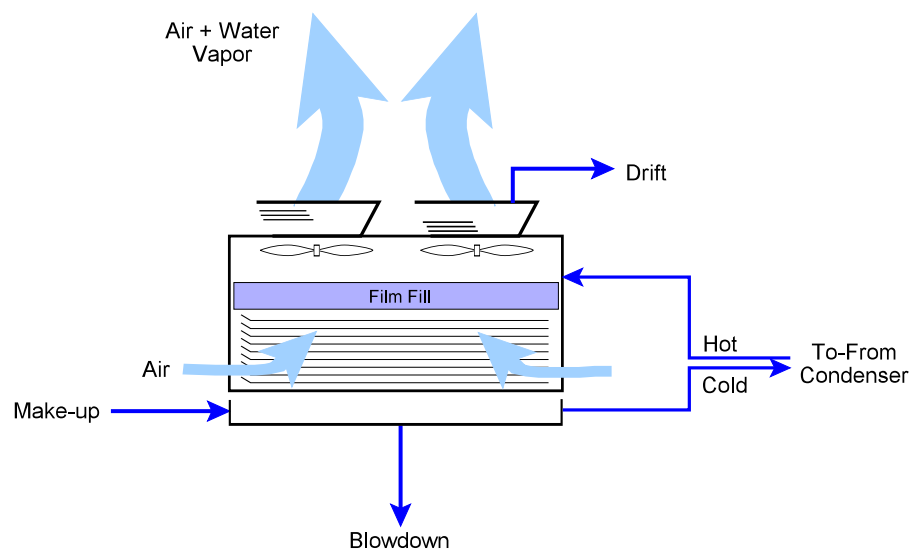


Degraded Water for Power Plant Cooling

Workshop on Water Supply Issues
February 8, 2001

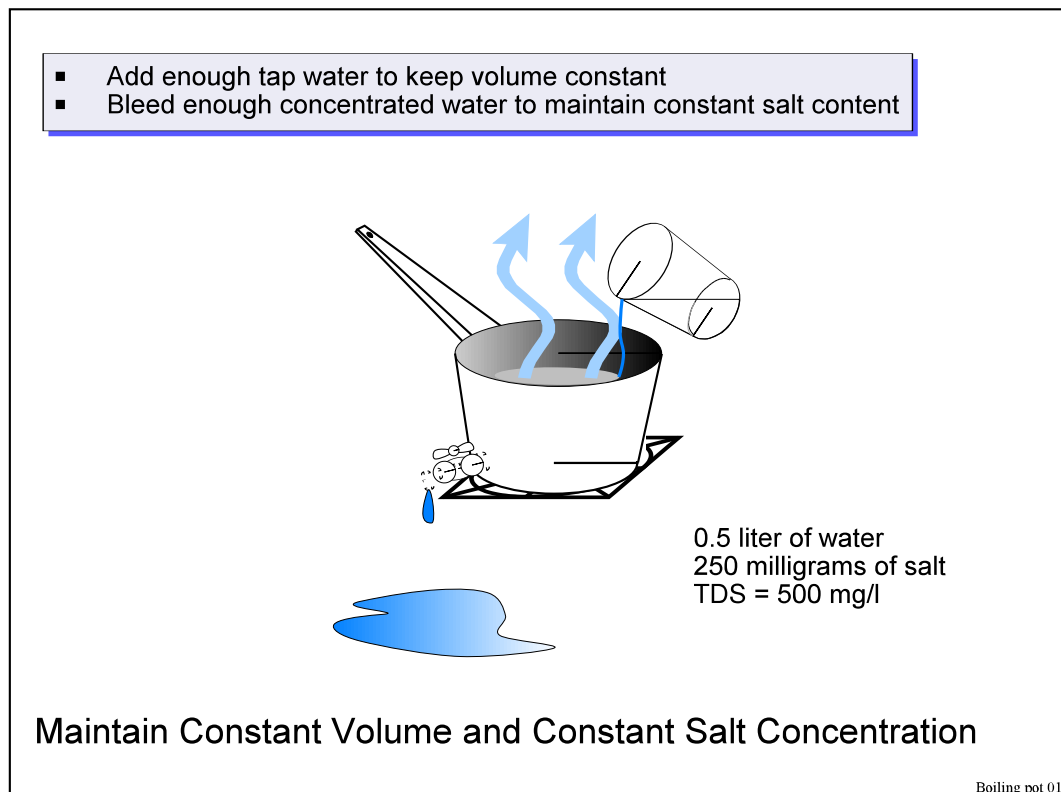
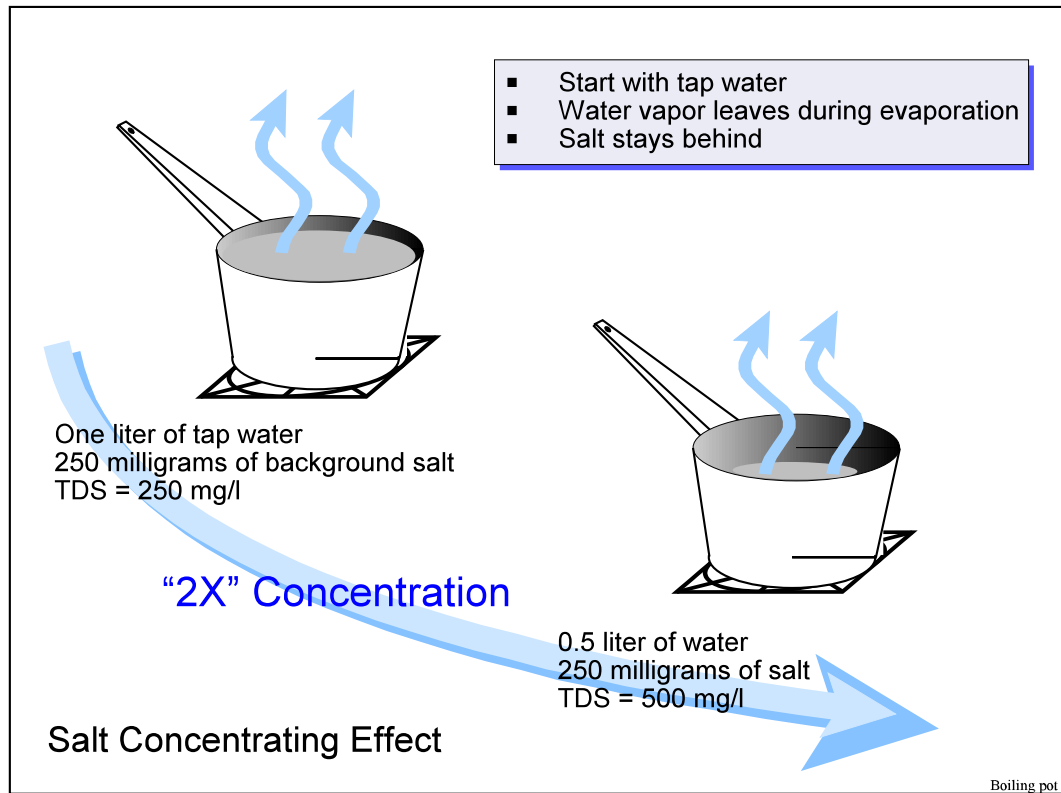
Presented by Michael N. DiFilippo, Consultant

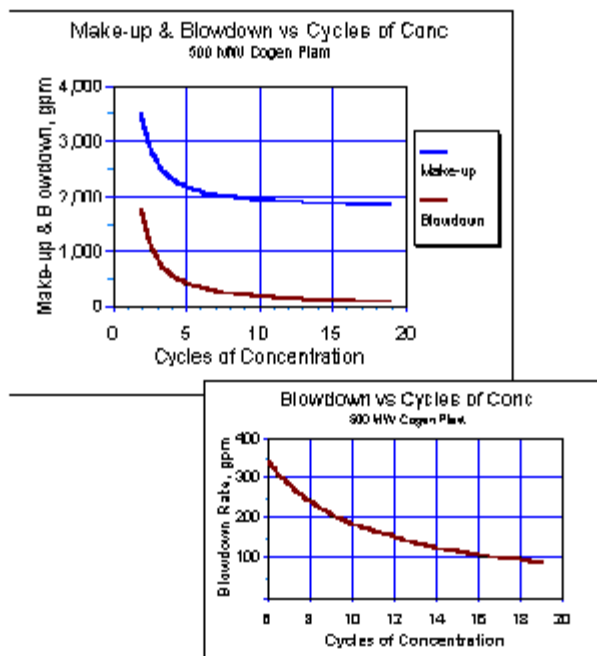
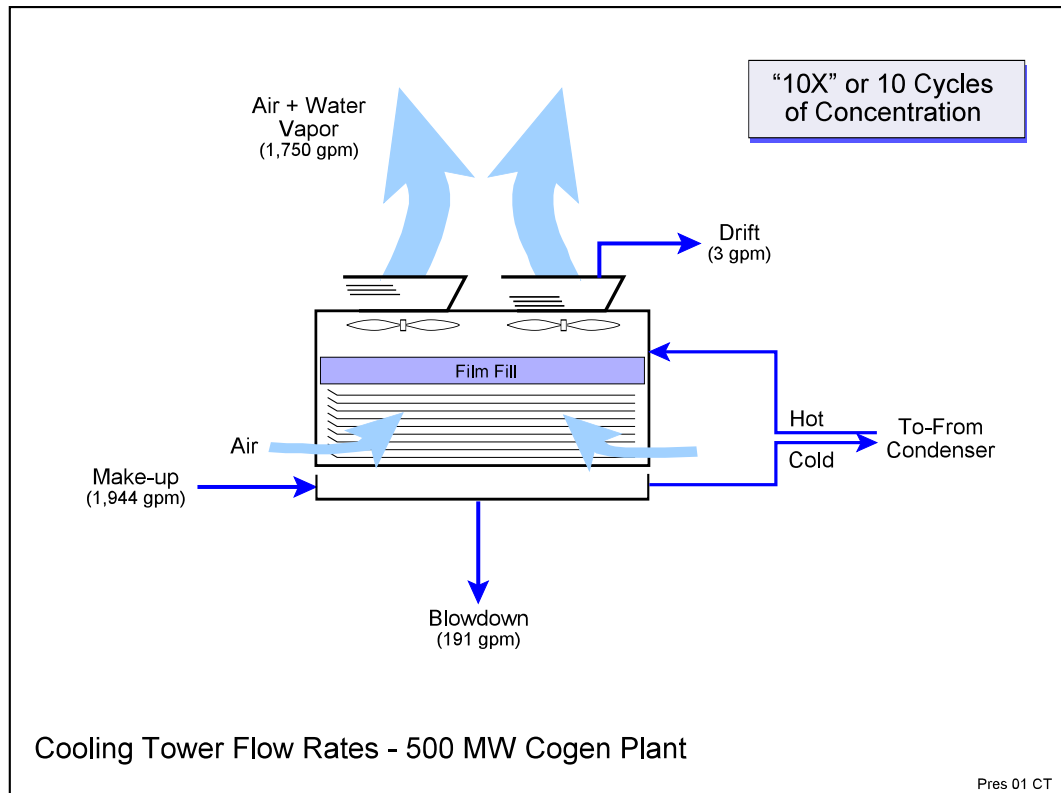
Pres 11 CT



Cooling Tower Basics

Pres 02 CT





Degraded Water Sources

- Contaminated Groundwater
- Brackish Surface Water
- Brackish Groundwater
- Agricultural Return Water
- Reclaimed Municipal Effluent
- Industrial Process Water or Wastewater

Pres 12 CT

Cooling System Chemistry Issues

- Common Minerals - calcium, magnesium, alkalinity, sulfate, silica, salinity
- Reclaimed Water Constituents (Title 22) - BOD, COD, THM precursors, ammonia, phosphate
- Hazardous Contaminants - heavy metals, VOCs, non-VOCs, pesticides
- Other Chemical Constituents - perchlorate, nitrate, sulfide, fluoride

Pres 03 CT

Table 2-3a

Cooling Tower - Basic Water Quality Parameters*Degraded Water TC*

Parameter	Units	Basic Parameters	
Ca	mg/l _{CaCO3}	900 (max)	
Ca with PO ₄ present	mg/l _{CaCO3}	(Refer to Table 2-1b)	
Ca x SO ₄	(mg/l) ²	500,000	
Mg x SiO ₂	mg/l _{CaCO3} x mg/l _{SiO2}	35,000 (2)	75,000 (3)
HCO ₃ + CO ₃	mg/l _{CaCO3}	30-50 (2)	200-250 (3)
SO ₄	mg/l	(Note 5)	
SiO ₂	mg/l	150	
Fe (Total)	mg/l	<0.5 (5)	
Mn	mg/l	<0.5	
Cu	mg/l	<0.1	
Al	mg/l	<1	
S	mg/l	5	
NH ₃	mg/l	<2 (9)	
pH		6.8-7.2 (2)	7.8-8.4 (3)
pH with PO ₄ present		7.0-7.5 (4)	
TDS	mg/l	70,000	
TSS	mg/l	<100 (6) - <300 (7)	
BOD	mg/l	<100 (4)	
COD	mg/l	<100 (4)	
Langelier SI (8)		<0	
Ryznar SI (8)		>6	

Notes.....

1. Cooling tower circulating water concentrations. PO₄ refers to total phosphate concentration. Refer to Table 3-1 and for detailed calculation procedures.
2. Without scale inhibitor.
3. Assumes scale inhibitor is present.
4. Consult with specialty chemical provider before finalizing control parameters.
5. Refer to the CaSO₄ limit.
6. <100 mg/l TSS with film fill.
7. <300 mg/l TSS with open fill.
8. Refer to Appendix A for a discussion of the Langelier and Ryznar Saturation Indices for calcium carbonate.
9. <2 mg/l NH₃ applies when copper bearing alloys are present in the cooling system. This does not apply to 70-30 or 90-10 copper nickel.

Table 2-3b

Maximum Cooling Tower Calcium with PO₄ Present*Degraded Water TC*

pH	PO ₄ mg/l	Max Ca, mg/l CaCO ₃ @ Cooling Tower TDS, mg/l				
		500	2,500	5,000	10,000	20,000
7.00	5	110	160	200	250	285
7.25	5	70	100	130	165	190
7.50	5	40	65	85	105	125
7.00	10	70	100	125	160	180
7.25	10	45	65	80	105	120
7.50	10	25	40	50	65	80
7.00	15	55	75	95	120	140
7.25	15	35	50	60	80	90
7.50	15	20	30	40	50	60

Notes.....

1. Cooling tower circulating water concentrations. PO₄ refers to total phosphate concentration. Refer to Table 3-1 and for detailed calculation procedures.
2. Assumes scale inhibitor is present.
3. Consult with specialty chemical provider before finalizing control parameters.

Table 2-2

Degraded Water Categories*Degraded Water TC*

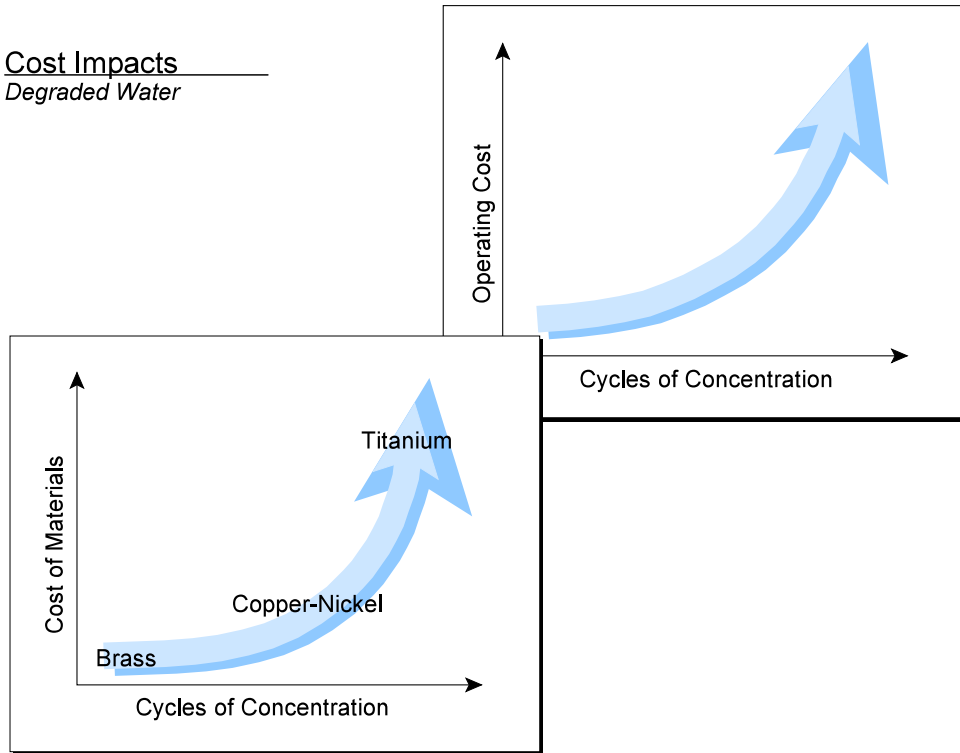
	General Minerals (Note 3)	Biological (Note 4)	Organic Compounds (Note 5)	Metals (Note 6)	Other (Note 7)
Fresh water ^①	✓		(Note 10)	(Note 10)	
Reclaimed water	✓	✓	(Note 10)	(Note 10)	✓
Industrial process water ^②	✓	✓	✓	✓	✓
Degraded water					
♦ Agricultural return water ^③	✓		✓	✓	✓
♦ Dairy or feed-lot runoff	✓	✓	✓		✓
♦ Brackish water ^④	✓			✓	✓
♦ Contaminated groundwater	✓		✓	✓	✓

Notes.....

1. Selenium has been identified as a heavy-metal contaminant in some agricultural tailwaters.
2. Surface or groundwater with TDS >1,500 mg/l.
3. General Minerals Na, K, Ca, Mg, HCO₃, CO₃, Cl, SO₄ and SiO₂.
4. Biological BOD, COD, NH₃, PO₄, THM, etc. Typically found in reclaimed wastewater as well as pharmaceutical, biotech, livestock/dairy and food processing waste streams.
5. Organics Volatile, non-volatile or pesticide compounds
6. Metals Ba, Sr, Fe, Mn, Cu, Zn, Se, As, Cr, Hg, etc.
7. Other NO₃, PO₄, ClO₄, S, F, etc.
8. Can be surface water or groundwater. Many supplies contain trace levels of organic compounds and metals.
9. Examples are produced water (oil production), micro-electronics wastewater, mine sluice water, electroplating rinse water, etc.
10. Trace concentrations of organics and metals (within regulatory limits) are found in many fresh water supplies.

Cost Impacts

Degraded Water



Pres 13 CT

Pre-Treatment

- Remove Organic Compounds
- Remove Pesticides
- Remove Heavy Metals
- Adjust pH
- Soften
- Reduce Silica
- Reduce TDS
- Reduce TSS

Specialty chemicals

Side-Stream Treatment

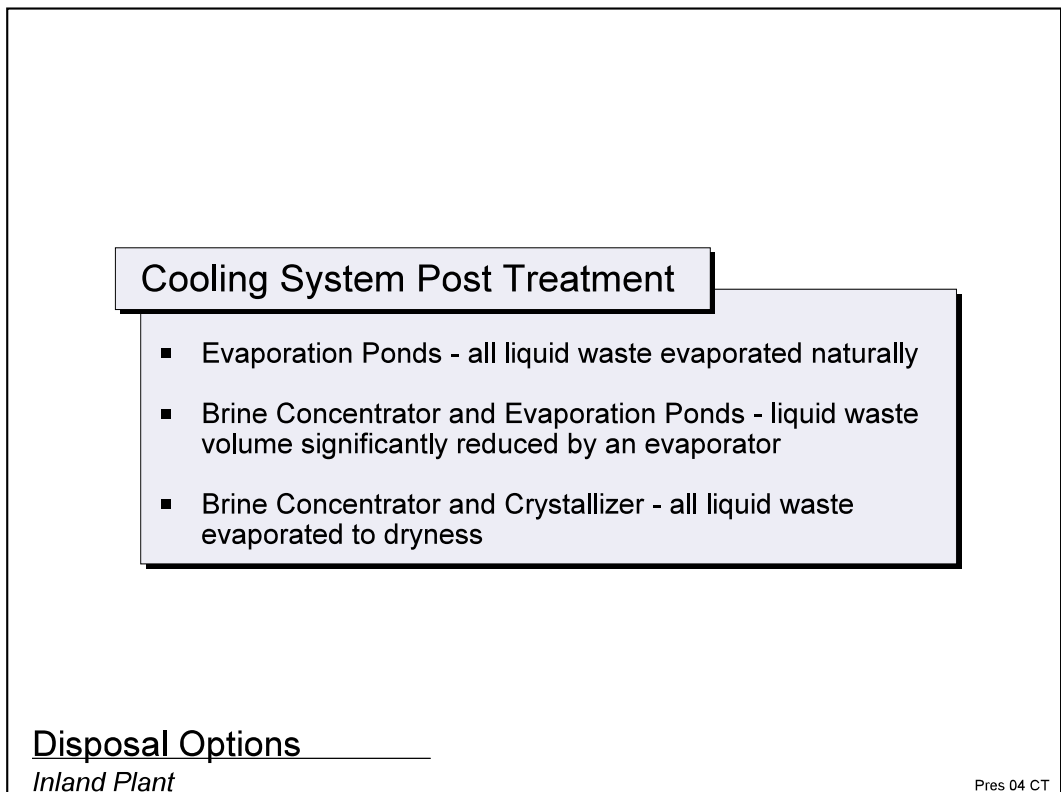
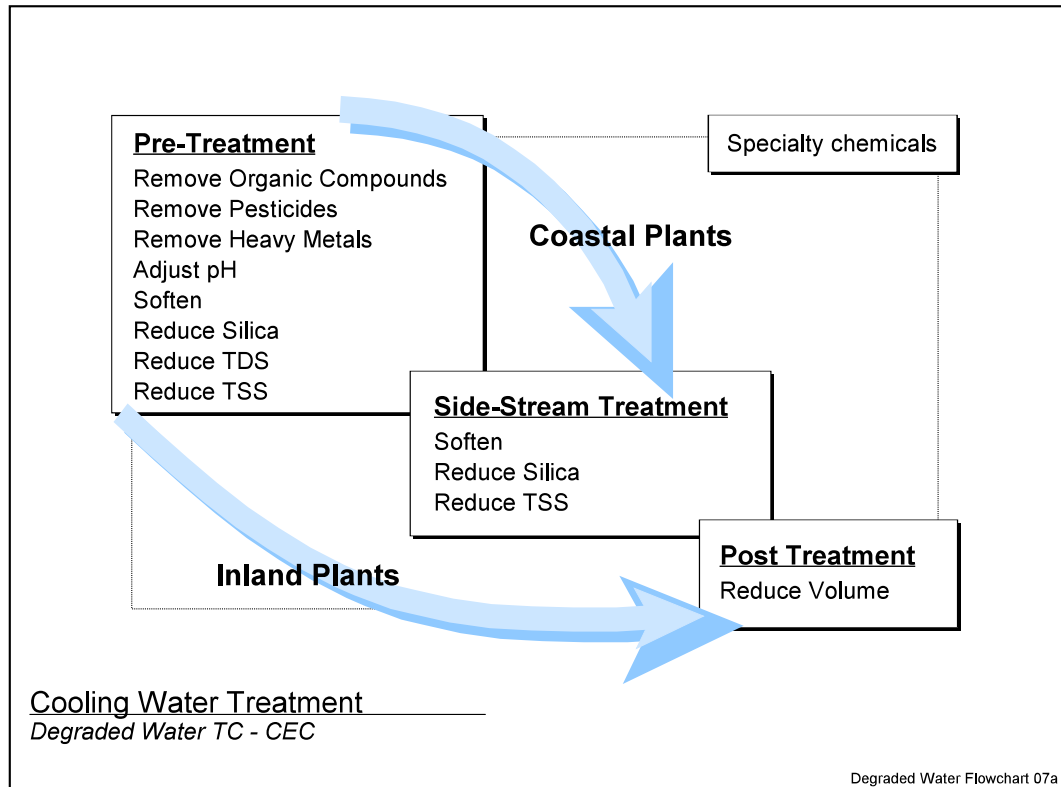
- Soften
- Reduce Silica
- Reduce TSS

Post Treatment

- Reduce Volume

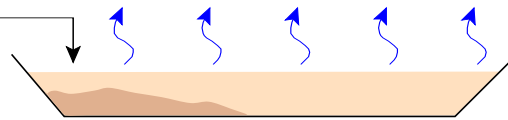
Cooling Water Treatment

Degraded Water TC - CEC



- 500 MW Cogen Plant
- Cooling tower operated at 10 cycles of concentration
- 191 gpm of cooling tower blowdown
- 10 gpm of miscellaneous plant wastewater

Total Plant Wastewater
201 gpm



Evaporation Pond
98 acres (Central Valley)
66 acres (Desert)

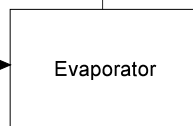
Disposal Option 1 - Evaporation Pond

Inland Plant

Pres 07 CT

- 500 MW Cogen Plant
- Cooling tower operated at 10 cycles of concentration
- 191 gpm of cooling tower blowdown
- 10 gpm of miscellaneous plant wastewater

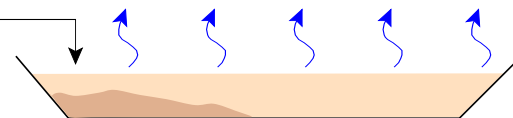
Total Plant Wastewater
201 gpm



High-Quality Distillate to Re-Use
181 gpm

Electric Power Requirement
0.98 MW

Concentrated Waste - 90% Reduction
20 gpm



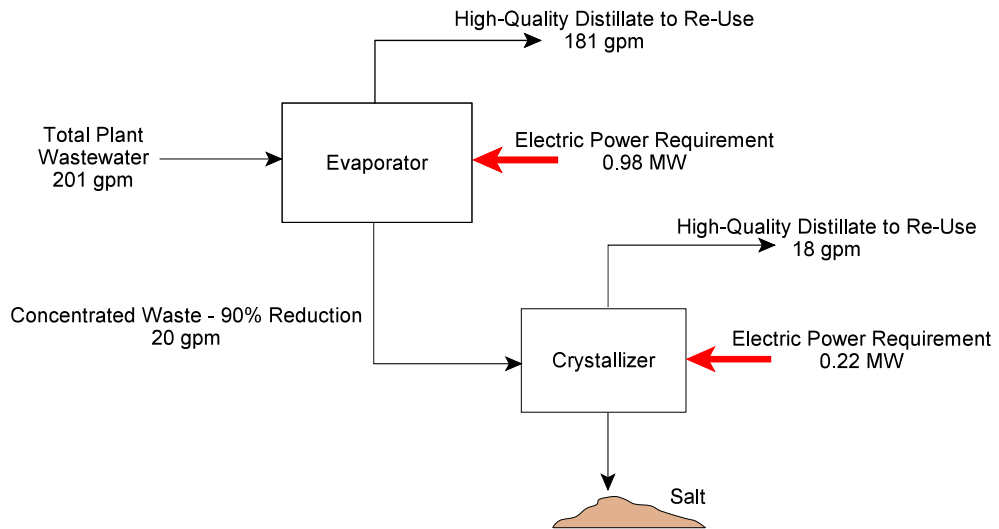
Evaporation Pond
9.8 acres (Central Valley)
6.6 acres (Desert)

Disposal Option 2 - Evaporator + Evaporation Pond

Inland Plant

Pres 06 CT

- 500 MW Cogen Plant
- Cooling tower operated at 10 cycles of concentration
- 191 gpm of cooling tower blowdown
- 10 gpm of miscellaneous plant wastewater



Disposal Option 3 - Evaporator + Crystallizer

Inland Plant

Pres 08 CT

- 500 MW Cogen Plant
- Cooling tower operated at 10 cycles of concentration
- 191 gpm of cooling tower blowdown
- 10 gpm of miscellaneous plant wastewater

Central Valley

	Option 1	Option 2	Option 3
Evap Pond Area, Acres	94	9.4	NA
Evaporator Power, MW	NA	0.98	0.98
Crystallizer Power, MW	NA	NA	0.22

Desert

	Option 1	Option 2	Option 3
Evap Pond Area, Acres	63	6.3	NA
Evaporator Power, MW	NA	0.98	0.98
Crystallizer Power, MW	NA	NA	0.22

Disposal Option Summary

Inland Plant

Pres 09 CT

- 500 MW Cogen Plant
- Cooling tower operated at 10 cycles of concentration
- 191 gpm of cooling tower blowdown
- 10 gpm of miscellaneous plant wastewater

Central Valley

	<u>Installed Cost, \$million</u>		
	<u>Option 1</u>	<u>Option 2</u>	<u>Option 3</u>
Evap Pond	\$32.9	\$3.3	NA
Evaporator	NA	\$3.4	\$3.4
Crystallizer	<u>NA</u>	<u>NA</u>	<u>\$2.3</u>
Total	\$32.9	\$6.7	\$5.7

Desert

	<u>Installed Cost, \$million</u>		
	<u>Option 1</u>	<u>Option 2</u>	<u>Option 3</u>
Evap Pond	\$22.1	\$2.2	NA
Evaporator	NA	\$3.4	\$3.4
Crystallizer	<u>NA</u>	<u>NA</u>	<u>\$2.3</u>
Total	\$22.1	\$5.6	\$5.7

Disposal Cost Summary_____

Inland Plant

Pres 10 CT